SOLENOID WITH NOISE REDUCTION

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims the benefit of U.S. Provisional Application No. 60/470,609, filed May 15, 2003, and also claims the benefit of U.S. Provisional Application No. 60/511,421, filed October 13, 2003, the entire contents of each of which are incorporated by reference.

BACKGROUND OF THE INVENTION

[0002] Various types of solenoids have been developed to provide electrically powered linear motion. Such solenoids typically include either a soft magnetic material or a permanent magnet comprising the moving mass, and a coil. When the solenoid is in the deenergized or rest position, a portion of the moving mass is in contact with a stop surface. When the coil is electrically energized, the moving mass shifts away from the stop surface. When the coil is deenergized, the moving mass shifts back to the rest position, contacting the stop surface. The impact of the moving mass on the stop surface can create substantial noise that may not be acceptable for certain applications. Efforts to reduce this noise have included utilizing a separate resilient member such as a rubber washer or the like to reduce the noise otherwise caused by the moving mass impacting the stop surface when it shifts to the rest position.. However, such resilient stops create added complexity and costs, and may also be prone to degradation.

SUMMARY OF THE INVENTION

[0003] One aspect of the present invention is a solenoid having a housing and a coil disposed in the housing for generating a magnetic field when an electric current passes through the coil. A center pole is disposed within the coil, and the center pole is made of a ferromagnetic material. A rod assembly is movably disposed in the housing for movement between a rest position and an energized position. The rod assembly has a portion thereof disposed in the center pole, and includes a magnet having a polarity causing the magnet to be repelled from the center pole when an electric current passes through the coil. The magnet is encapsulated by an

elastomeric material that contacts a stop surface when in the rest position to reduce noise resulting from shifting of the rod assembly from the energized position to the rest position.

[0004] Another aspect of the present invention is a rod assembly for an electrically powered linear actuator. The rod assembly includes an elongated body made of a first material having a first melting temperature. A magnet is connected to the elongated body, and a second material encapsulates at least a portion of the magnet. The second material has a second melting temperature that is less than the first melting temperature.

[0005] Yet another aspect of the present invention is a method of making a rod assembly for an electrically powered linear actuator. The method includes molding a body portion of a first material having a first reflow temperature. A magnet is provided, and the magnet is overmolded with a second material having an injection molding temperature that is less than the reflow temperature of the first material to thereby form a damper.

[0006] These and other features, advantages, and objects of the present invention will be further understood and appreciated by those skilled in the art by reference to the following specification, claims, and appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Fig. 1 is an exploded perspective view of a solenoid according to one aspect of the present invention;

[0008] Fig. 2 is a cross-sectional view of the solenoid of Fig. 1 when in an assembled condition;

[0009] Fig. 3 is a cross-sectional view of the rod assembly of the solenoid of Fig. 1; and

[0010] Fig. 4 is an enlarged view of a portion of the rod assembly.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

[0011] For purposes of description herein, the terms "upper," "lower," "right," "left," "rear," "front," "vertical," "horizontal," and derivatives thereof shall relate to the invention as oriented in Fig. 1. However, it is to be understood that the invention may assume various alternative orientations and step sequences, except where expressly specified to the contrary. It is also to be understood that the specific devices and processes illustrated in the attached drawings and described in the following specification are simply exemplary embodiments of the inventive concepts defined in the appended claims. Hence, specific dimensions and other

physical characteristics relating to the embodiments disclosed herein are not to be considered as limiting, unless the claims expressly state otherwise.

[0012] With reference to Fig. 1, a solenoid 1 according to the present invention includes a flux washer 2, spring 3, coil bobbin assembly 4, a rod assembly 5, center pole 6, and housing 7. The flux washer 2, center pole 6, and housing 7 are preferably made of steel or other ferromagnetic material to increase the force of the magnetic field generated by the coil bobbin assembly 4. The coil bobbin assembly 4 is of a substantially conventional design, and includes an electrical coil 8 and electrical connectors 9 to provide an electrical field for actuating the solenoid 1.

[0013] With further reference to Fig. 2, when in an assembled condition, the center pole 6 is secured to the housing 7, and the rod assembly 5 has a portion 10 thereof disposed within the center pole 6. The rod assembly 5 includes a magnet 11 that is generally ring-like, with a polarity that causes the rod assembly 5 to shift in the direction of the arrow "A" when the coil 8 is energized. The rod assembly 5 shifts to the position "B" shown in dashed lines when the coil 8 is energized. When in the position B, the spring 3 contacts the inner surface 12 of flux washer 2, and compresses to cause a force tending to bias the rod assembly 5 to the rest or deenergized position. Also, because the center pole 6 is made of steel or other ferromagnetic material, the magnet 11 also has a magnetic attraction to the center pole 6 tending to return the rod assembly 5 to the rest position. The length of the spring 3 may be selected such that a gap is formed between the end 13 of spring 3 and surface 12 when rod assembly 5 is in the rest position. The length and the stiffness of the spring 3 can then be selected to provide just enough force to move the rod assembly 5 to a point close enough to center pole 6 wherein the magnetic force of the magnet 11 is sufficient to move the rod assembly 5 to the rest position by itself, without further assist from the spring 3. In this way, the amount of force required to overcome the bias of spring 3 can be minimized, thereby minimizing the force that must be generated by the coil 8 and magnet 11 to retain the rod assembly 5 in the extended or energized position. Spring 3 may be not be necessary if the desired travel of the rod assembly is small enough such that the force of the magnet 11 is sufficient enough to move the rod assembly 5 to the rest position by itself.

[0014] With further reference to Figs. 3 and 4, the rod assembly 5 includes a body portion 14 that is preferably made of a polymer material such as a glass fiber reinforced nylon material. A damper 15 is made of an elastomeric material, and is molded around the magnet 11 to thereby encapsulate the magnet 11. The damper 15 is preferably made of a material having between about thirty-five to ninety Shore A durometer material, most preferably about sixty Shore A. The particular hardness and other material properties selected will depend upon the degree of noise reduction, durability, and the like required for a particular application. Also, the elastomeric material utilized to mold the damper 15 has an injection molding temperature that is less than the reflow temperature of the polymer material of the body 14 of rod assembly 5. An end piece 16 is made of a non-ferromagnetic material, such as austenitic stainless steel. The end piece 16 provides a structurally strong engagement member that is capable of reacting relatively large shear loads when the solenoid 1 is used in applications such as in an electrical pawl for a shifter of a motor vehicle. The end piece 16 may be made of other non-ferromagnetic materials having the required degree of strength, impact resistance, wear characteristics, and the like as required for a particular application. The end piece 16 includes a connector portion 17 that extends in the direction of the axis 18 of rod assembly 5. Connector 17 includes a portion 19 having a circular cross-sectional shape, and an end portion 20 that also has a circular cross-sectional shape. End portion 20 has a larger diameter than portion 19, such that the end piece 16 is securely connected to the main body portion 14.

[0015] During fabrication, the end piece 16 is positioned in a mold (not shown), and the body portion 14 is molded around the connector 17 of end piece 16. The magnet 11 is also positioned in the mold prior to the molding process. The mold shape is such that the body portion 14 forms outwardly extending flanges 21 and 22 in contact with the opposite side surfaces 23 and 24 of magnet 11. The magnet 11 is thereby securely molded to the body portion 14. After the body 14 is formed, the damper 15 is then molded over the magnet 11 and flanges 21 and 22 to thereby encapsulate the magnet 11.

[0016] The integral damper formed by overmolding the magnet provides a durable, cost effective way to reduce noise that would otherwise occur during operation of the solenoid. Furthermore, if the magnet is made of a material tending to flake or otherwise degrade,

encapsulating the magnet with the dampening material prevents pieces of the magnet from becoming loose and potentially interfering with proper operation of the solenoid.

[0017] In the foregoing description, it will be readily appreciated by those skilled in the art that modifications may be made to the invention without departing from the concepts disclosed herein. Such modifications are to be considered as included in the following claims, unless these claims by their language expressly state otherwise.